Evaluation of a Sulfonate Bait with Laboratory Fire Ant Colonies
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Abstract: A potassium perfluoroalkyl sulfonate bait was tested with standardized laboratory fire ant colonies. This bait produced 100% colony kill over a 100-fold concentration range (1.0 - 0.01%). The bait had good palatability, delayed mortality and was easily to formulate. These results are promising; nevertheless, further tests are needed to determine field effectiveness and environmental acceptability.

Introduction

The red imported fire ant (Solenopsis invicta) is considered a major pest throughout the Southeastern United States primarily because of its potent sting. This pest may also damage certain crops (Lofgren 1986) and reduce native arthropod diversity (Porter and Savignano 1990). Over the years, thousands of chemicals have been tested for use in fire ant baits (Williams et al. 1987). Recent studies have shown that a number of fluoroaliphatic sulfones show potential for use in baits and drenches (Vander Meer et al. 1985, Williams et al. 1987, Lofgren et al. 1989). Two sulfonates were tested (Vander Meer et al. 1985), but eliminated from further screening because of poor oil solubility. This study was designed to evaluate the effectiveness of a new sulfonate bait formulation on laboratory fire ant colonies (S. invicta).

Materials and Methods

The active ingredient in test baits was potassium perfluoroalkyl sulfonate (predominantly, $C_8F_{17}SO_3K$ plus some $C_6F_{13}SO_3K$ and a little $C_7F_{15}SO_3K$) manufactured by the 3M Company (St. Paul, Minn.). This compound is sold as a fluorosurfactant under the trade name of FLUORAD™ FC-95 (I.D. No. 98-0207-0103-7). Vander Meer et al. (1985) assigned this compound the code number of AI3-50950 in their screening tests. Test baits were formulated by dissolving the sulfonate in acetone and then mixing the solution with a corn meal carrier. The acetone was then evaporated off, leaving the corn meal impregnated with the toxin. Soybean oil was added as an attractant (5% by final weight of the bait).

Two experiments were conducted. The first experiment contained five groups: a control group, an Affirm® standard, and three test groups which received baits with sulfonate concentrations of 1.0%, 0.3% and 0.05% (as a fraction of the total bait). The second experiment contained seven groups: a control group, an Amdro® standard, and five test groups which received sulfonate baits of 1.0%, 0.1%, 0.1%, 0.01%, and 0.001%. Each group consisted of three standardized test colonies.

Test colonies initially contained 5 queens, 5 g of workers and 0.5 g of brood (first experiment) or 2 g of brood (second experiment). These colonies were formed from a mixture of five multiple-queen field colonies. Field colonies were mixed to provide a large and relatively homogeneous source of workers and brood for the test colonies. Care and handling procedures were similar to those described by Banks et al. (1981). Test colonies were maintained at 32°C and fed crickets and 1 M sugar water every other day. Poison baits were introduced one week after the test colonies were established. Sugar water and solid food were withheld for 2 days prior to treatment. Normal feeding resumed immediately after removal of the test baits.

Excess quantities of all baits were provided for 24 h; bait not collected during this period was removed and discarded. Bait removed from the feeding tray was allowed to remain in the nest for the duration of the experiment except for one of the two 0.1% test groups in the second experiment. In this group, all unconsumed bait was removed after 48 h in order to determine if results with other test groups could be attributed to continued feeding on bait stored in the nest. Percent mortality of workers and brood was determined by comparison with the control colonies. The size of control colonies remained relatively constant during the experiment because growth was limited by nest size and the amount of food provided. Queen mortality was determined by counting the living queens.

Results

The sulfonate baits were very effective in killing laboratory fire ant colonies. All test colonies were killed in treatment groups receiving baits with 1.0%, 0.3%, 0.1%, 0.05% and 0.01% sulfonate (Table 1). By comparison, control colonies all remained healthy throughout the tests. Colonies receiving 0.001% bait had some worker mortality and 53% of the queens died by day 40 compared to 15% mortality of control queens ($P < 0.05$, $W = 17.5$, Wilcoxon rank sum test). These 0.001% colonies were followed for three months; one eventually died while the other two recovered and remained healthy.

Delayed mortality (> 24 h) was observed with all concentrations except the second trial with 1.0% sulfonate. It should be noted that the Amdro standard in this trial showed even less delay. At concentrations of 0.1% and above, workers died faster than the queens, but at lower concentrations, the reverse was true. This was especially evident with the 0.01% treatment where all of the queens died before the workers began dying. Brood generally died more slowly than the workers almost as if from neglect. In the 0.01% bait group, large numbers of workers died shortly after eclosing from pupae beginning about three weeks after treatment. Apparently, exposure of larvae to low doses of toxicant prevented eventual development into healthy workers. Removal of bait stored in the nest did not affect the mortality rate of colonies receiving 0.1% bait.

Sulfonate baits were about as attractive as the Affirm and Amdro standards. Generally, the amount of bait retrieved seemed to be limited mostly by small colony size and suitable places for the colony to store the bait. In the first experiment, colonies removed averages of 2.8±1.8 (S.D.), 1.6± 0.2, and 1.8±0.4 g of bait for the 0.05%, 0.3%, and 1.0% sulfonate treatments compared to 1.2±0 for the Affirm standard. In the second experiment, colonies removed averages of 3.4±0.4, 5.4±0.6, 4.0±1.1, and 1.8±0.7 g of bait for the 0.001%, 0.01%, 0.1%, and 1.0% treatments compared to 2.0±0.4 for the Amdro standard. The drop in retrieval at higher concentrations in the second experiment is probably attributable to high forager mortality in the first 24 h rather than reduced bait attractiveness.

Discussion

Results for the sulfonate baits were similar to those observed by Vander Meer et al. (1985); test baits showed delayed action and workers died at similar rates. Several differences need to be reported, however. Results in Table 1 clearly show that oil solubility is not necessary for the function of a sulfonate bait. Secondly, results in this paper suggest a much wider range of effective doses than indicated by Vander Meer et al. (1985). These authors rated sulfonates as class III compounds (effective dose range of < 10 fold, see Banks et al. 1977), but they did not explain how they reached this conclusion.

My tests indicate at least a 50-fold dose range for worker mortality and over a 100-fold range for queen mortality. The selective impact of low-dosages of sulfonate on queens is very interesting. Queens are usually the last colony members to die with other bait products. It is unknown whether queens are especially sensitive to sulfonates or whether the toxicant is preferentially directed to them. Overall, these results indicate that sulfonates should be rated as a class IV toxicant (10- to 100-fold dose range) based on worker mortality or a class V toxicant (>100-fold dose range) based on queen mortaliy. It should be pointed out that Vander Meer et al. (1985) did not test the effectiveness of sulfonates on queens and also that the small groups of workers which they used as test units may not be as sensitive as whole colonies; consequently, results of these two papers may not be directly comparable.

In summary, laboratory studies confirm that the sulfonate compound tested met four of five primary requirements for a good fire ant bait (Williams et al. 1987); that is: 1) delayed toxicity, 2) a broad effective dose range, 3) good palatability, and 4) easy formulation with carrier. The fifth requirement is that the toxicant be environmentally acceptable– this remains to be determined. The material data safety sheet provided by 3M (10-3796-9) indicates that this sulfonate is moderately toxic to vertebrates in acute doses (rat LD_{50} = 251 mg/kg, fish LC50 = 11-68 mg/l of water). Effects of chronic exposure indicate the compound is not mutagenic (Ames Assay) or teratogenic (rat: 5 mg/kg/day). The sulfonate tested is chemically inert; in other words, it does not decompose under normal environmental conditions or produce secondary degredation products. This increases the shelf-life of the bait, but it also means that the chemical is not easily detoxified.

While laboratory results were encouraging, sulfonate baits still need to be tested under field conditions. Also, the toxicant needs to be tested with a more versatile carrier such as the standard pregel defatted corn grits used in other baits.

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Table 1. Percent reduction in colony size (compared to control group) after treatment with a sulfonate bait. Each value is the mean of three test colonies. Percent mortality of queens is shown in parentheses.

Treatment	% Change across Time (days)								
	1	2	5	7	10	13	22	29	40
Experiment I									
Affirm®	17 (–)	67 (–)	95 (0)	95 (0)	95 (7)	96 (20)	98 (47)	98 (80)	100 (100)
sulfonate									
0.05%	0 (–)	0 (–)	5 (20)	18 (73)	47 (93)	75 (100)	83 (–)	97 (–)	100 (–)
0.3%	0 (–)	0 (–)	80 (53)	90 (73)	95 (93)	99 (100)	100 (–)		
1.0%	10 (–)	53 (–)	97 (67)	97 (87)	100 (93)	– (100)			
Experiment II									
Control	– (5)	– (5)	– (5)	– (5)	– (5)	– (10)	– (10)	– (10)	0 (20)
Amdro®	96 (7)	97 (7)	99 (40)	100 (67)	– (100)				
sulfonate									
0.001%	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (13)	0 (40)	13 (47)	23 (53)
0.01%	0 (0)	0 (0)	0 (26)	0 (73)	0 (93)	0 (100)	63 (–)	82 (–)	87 (–)
0.1%	1 (0)	9 (0)	78 (27)	80 (53)	91 (80)	99 (93)	100 (100)		
0.1%*	1 (0)	2 (0)	83 (13)	90 (66)	97 (80)	99 (87)	100 (100)		
1.0%	75 (13)	83 (27)	99 (73)	100 (80)	– (87)	– (100)			

*All unconsumed bait was removed from this treatment after 48 h.